- The maximum spacing between occurrences of a program_map_table containing television program information shall be 400 ms.
- The program numbers are associated with the corresponding PMT_PIDs in the PID0 Program Association Table. The maximum spacing between occurrences of section 0 of the program_association_table is 100 ms.
- The video elementary stream section shall contain the Data stream alignment descriptor described in Section 2.6.10 of ISO/IEC 13818-1. The alignment_type field shown in Table 2-47 of ISO/IEC 13818-1 shall be 0x02.
- Adaptation headers shall not occur in transport packets of the PMT_PID for purposes other than for signaling with the discontinuity_indictor that the version_number (Section 2.4.4.5 of ISO/IEC 13818-1) may be discontinuous.
- Adaptation headers shall not occur in transport packets of the PAT_PID for purposes other than for signaling with the discontinuity_indicator that the version_number (Section 2.4.4.5 of ISO/IEC 13818-1) may be discontinuous.

5.5 PES constraints

Packetized Elementary Stream syntax and semantics shall be used to encapsulate the audio and video elementary stream information. The Packetized Elementary Stream syntax is used to convey the Presentation Time-Stamp (PTS) and Decoding Time-Stamp (DTS) information required for decoding audio and video information with synchronism. This Section describes the coding constraints for this system layer.

Within the PES packet header, the following restrictions apply:

- PES_scrambling_control shall be coded as '00'.
- ESCR_flag shall be coded as '0'.
- ES_rate_flag shall be coded as '0'.
- PES_CRC_flag shall be coded as '0'.

Within the PES packet extension, the following restrictions apply.

- PES_private_data_flag shall be coded as '0'.
- pack_header_field_flag shall be coded as '0'.
- program_packet_sequence_counter_flag shall be coded as '0'.
- P-STD_buffer_flag shall be coded as '0'.

5.5.1 Video PES constraints

Each PES packet shall begin with a video access unit, as defined in Section 2.1.1 of ISO/IEC 13818-1, which is aligned with the PES packet header. The first byte of a PES packet payload shall be the first byte of a video access unit. Each PES header shall contain a PTS. Additionally, it shall contain a DTS as appropriate. For terrestrial broadcast, the PES packet shall not contain more than one coded video frame, and shall be void of video picture data only when transmitted in conjunction with the discontinuity_indicator to signal that the continuity_counter may be discontinuous.

Within the PES packet header, the following restrictions apply:

- The PES_packet_length shall be coded as '0x0000'.
- data_alignment_indicator shall be coded as '1'.

5.5.2 Audio PES constraints

The audio decoder may be capable of simultaneously decoding more than one elementary stream containing different program elements, and then combining the program elements into a complete program. In this case, the audio decoder may sequentially decode audio frames (or audio blocks) from each elementary stream and do the combining (mixing together) on a frame or (block) basis. In order to have the audio from the two elementary streams reproduced in exact sample synchronism, it is necessary for the original audio elementary stream encoders to have encoded the two audio program elements frame synchronously; i.e., if audio program 1 has sample 0 of frame n at time t0, then audio program 2 should also have frame n beginning with its sample 0 at the identical time t0. If the encoding is done frame synchronously, then matching audio frames should have identical values of PTS.

If PES packets from two audio services that are to be decoded simultaneously contain identical values of PTS then the corresponding encoded audio frames contained in the PES packets should be presented to the audio decoder for simultaneous synchronous decoding. If the PTS values do not match (indicating that the audio encoding was not frame synchronous) then the audio frames which are closest in time may be presented to the audio decoder for simultaneous decoding. In this case the two services may be reproduced out of sync by as much as 1/2 of a frame time (which is often satisfactory, e.g., a voice-over does not require precise timing).

The value of stream_id for AC-3 shall be 1011 1101 (private_stream_1).

5.6 Services and features

5.6.1 Network map and program guide

The Network PID identified as Program 0 in the Program Association Table is available to provide information relating to present and future programs. This information can be used to provide a program guide in suitably-equipped receivers. In order to implement the program guide, the syntax and semantics of the stream carrying the information must be specified and standardized. This specification is not included in this standard.

5.6.2 Specification of private data services

Private data provides a means to add new ancillary services to the basic digital television service specified in this standard. Private data is supported in two bit stream locations.

1. Private data can be transmitted within the adaptation header of transport packets (Sections 2.4.3.4 and 2.4.3.5 of ISO/IEC 13818-1).
2. Private data can be transmitted as a separate transport stream with its own PID. The contents can be identified as being ATSC private by using the private_data_indicator_descriptor (Section 2.6.29 of ISO/IEC 13818-1) within the PMT.

In either case, it is necessary that the standards which specify the characteristics of such private_streams be consistent with the Digital Television Standard. Standards for private_streams shall precisely specify the semantics of the transmitted syntax as described in Sections 5.6.2.1 and 5.6.2.1.1.

5.6.2.1 Verification model

The standard shall be specified in terms of a verification model by defining the characteristics of the transmitted syntax and an idealized decoder. In ISO/IEC 13818-1 and 13818-2, this is accomplished by using the T-STD and VBV models, respectively. The elements required for specification by this Standard are described in the following Sections.

5.6.2.1.1 Syntax and semantics

The syntax and semantics of the transmitted bit stream that implements the ancillary service shall be completely and unambiguously specified. The decoding process shall also be completely and unambiguously specified.

5.6.2.1.2 Ancillary service target decoder (ASTD)

An idealized decoder model must be precisely defined for the service. Figure 2 introduces a concrete model for pedagogic purposes. It is modeled after the T-STD.

The salient features of the model are the size of the transport demultiplexing buffer (TB), the minimum transfer rate out of the transport demultiplex buffer (R_{leak}), the required System buffering (BS_{sys}), and optionally the partitioning of BS_{sys} between the smoothing portion and the decoder portion. The decoding process, represented as the decoding times T_decode(i), must be completely specified. The behavior of the BS_{sys} buffer must be completely modeled with respect to its input process and its output process. Certain parameters of the service such as bit rate, etc., should also be specified.

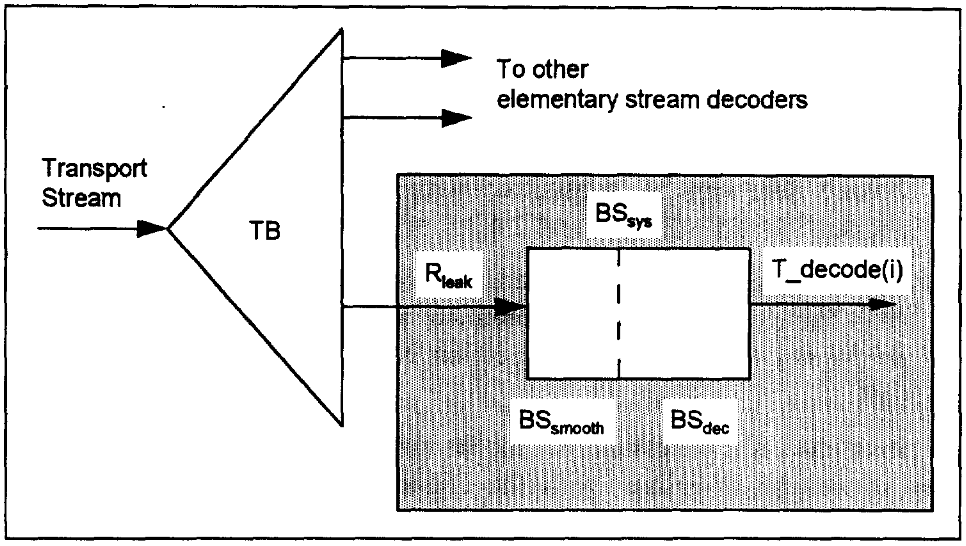

Figure 2. Ancillary service target decoder.

5.6.2.2 Stream type and PMT descriptors

A new ancillary service shall be described as a program or elementary stream through documented Program Specific Information.

5.6.2.2.1 Stream type

Several identifiers that are part of the transport section of the Digital Television Standard may be used to identify either the signal or constituent parts thereof; however, the fundamental identifier is the User Private stream type. The stream_type codes shall be unambiguously assigned within the range 0x80 to 0xAF. 0x81 has already been assigned within the Digital Television Standard (see Section 5.7.1).

5.6.2.2.2 PMT descriptors

The Ancillary Service specification shall include all pertinent descriptors that are found within the Program Map Table. Specifically, it is recommended that either the private_stream_identifier or the registration_descriptor, or both, be included. Although this is not required for a stream with a unique stream_type code within this Standard, it will enhance interoperability in the case where the stream is stored outside this Standard, or transmitted in some other network that has its own set of stream_type codes.

5.7 Assignment of Identifiers

In this Section, those Identifiers and codes which shall have a fixed value are summarized. These include PES Stream IDs and Descriptors. Stream_type codes from 0x80 to 0xAF shall be reserved for assignment as needed within the Digital Television Standard. Descriptor_tag codes from 0x40 to 0xAF shall be reserved for assignment as needed within the Digital Television Standard.

5.7.1 Stream type

The AC-3 audio stream_type shall have the value 0x81.

5.7.2 Descriptors

5.7.2.1 AC-3 audio descriptor

In the digital television system the AC-3 audio descriptor shall be included in the TS_program_map_section. The syntax is given in Table 2 of Annex A of ATSC Standard A/52. There are the following constraints on the AC-3 audio descriptor:

- The value of the descriptor_tag shall be 0x81.
- If textlen exists, it shall have a value of '0x00'.

5.7.2.2 Program smoothing buffer descriptor.

The Program Map Table of each program shall contain a smoothing buffer descriptor pertaining to that program in accordance with Section 2.6.30 of ISO/IEC 13818-1. During the continuous existence of a program, the value of the elements of the smoothing buffer descriptor shall not change.

The fields of the smoothing buffer descriptor shall meet the following constraints:

- The field sb_leak_rate shall be allowed to range up to the maximum transport rates specified in Section 7.2.
- The field sb_size shall have a value less than or equal to 2048. The size of the smoothing buffer is thus ≤ 2048 bytes.

5.8 Extensions to the MPEG-2 Systems specification

This Section covers extensions to the MPEG-2 Systems specification.

5.8.1 Scrambling control

The scrambling control field within the packet header allows all states to exist in the digital television system as defined in Table 2.

Table 2 Transport Scrambling Control Field

transport_ scrambling_ control	Function
00	packet payload not scrambled
01	not scrambled, state may be used as a flag for private use defined by the service provider.
10	packet payload scrambled with "even" key
11	packet payload scrambled with "odd" key

Elementary Streams for which the transport_scrambling_control field does not exclusively have the value of '00' for the duration of the program, must carry a CA_descriptor in accordance with Section 2.6.16 of ISO/IEC 13818-1.

The implementation of a digital television delivery system that employs conditional access will require the specification of additional data streams and system constraints.

6. FEATURES OF 13818-1 NOT SUPPORTED BY THIS STANDARD

The transport definition is based on the MPEG-2 Systems standard, ISO/IEC 13818-1; however, it does not implement all parts of the standard. This Section describes those elements which are omitted from this Standard.

6.1 Program streams

This Standard does not include those portions of ISO/IEC 13818-1 and Annex A of ATSC Standard A/52 which pertain exclusively to Program Stream specifications.

6.2 Still pictures

This Standard does not include those portions of ISO/IEC 13818-1 Transport Stream specification which pertain to the Still Picture model.

7. TRANSPORT ENCODER INTERFACES AND BIT RATES

7.1 Transport encoder input characteristics

The MPEG-2 Systems standard specifies the inputs to the transport system as MPEG-2 elementary streams. It is also possible that systems will be implemented wherein the process of forming PES packets takes place within the video, audio or other data encoders. In such cases, the inputs to the Transport system would be PES packets. Physical interfaces for these inputs (elementary streams and/or PES packets) may be defined as voluntary industry standards by SMPTE or other standardizing organizations.

7.2 Transport output characteristics

Conceptually, the output from the transport system is a continuous MPEG-2 transport stream as defined in this Annex at a constant rate of T_r Mbps when transmitted in an 8 VSB system and $2T_r$ when transmitted in a 16 VSB system where:

$$T_r = 2 \, x \left(\frac{188}{208}\right)\left(\frac{312}{313}\right)\left(\frac{684}{286}\right) x \, 4.5 = 19.39\ldots Mbps$$

and

$$\left(\frac{684}{286}\right) x \, 4.5$$

is the symbol rate S_r in Msymbols per second for the transmission subsystem (see Section 4.1 of Annex D). T_r and S_r shall be locked to each other in frequency.

All transport streams conforming to this Standard shall conform to the ISO/IEC 13818-1 model.

Details of the interface for this output, including its physical characteristics, may be defined as a voluntary industry standard by SMPTE , or other standardizing organizations.

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ANNEX D

(Normative)

RF/TRANSMISSION CHARACTERISTICS

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ANNEX D

(Normative)

RF/TRANSMISSION CHARACTERISTICS

1. SCOPE

This Annex describes the characteristics of the RF/Transmission subsystem, which is referred to as the VSB subsystem, of the Digital Television Standard. The VSB subsystem has two modes: a terrestrial broadcast mode (8 VSB), and a high data rate cable mode (16 VSB). These are described in separate sections of this document.

2. NORMATIVE REFERENCES

There are no Normative References.

3. COMPLIANCE NOTATION

As used in this document, *"shall"* or *"will"* denotes a mandatory provision of the standard. *"Should"* denotes a provision that is recommended but not mandatory. *"May"* denotes a feature whose presence does not preclude compliance, that may or may not be present at the option of the implementor.

4. TRANSMISSION CHARACTERISTICS FOR TERRESTRIAL BROADCAST

4.1 Overview

The terrestrial broadcast mode (known as 8 VSB) will support a payload data rate of 19.28... Mbps in a 6 MHz channel. A functional block diagram of a representative 8 VSB terrestrial broadcast transmitter is shown in Figure 1. The input to the transmission subsystem from the transport subsystem is a 19.39... Mbps serial data stream comprised of 188-byte MPEG-compatible data packets (including a sync byte and 187 bytes of data which represent a payload data rate of 19.28... Mbps).

The incoming data is randomized and then processed for forward error correction (FEC) in the form of Reed-Solomon (RS) coding (20 RS parity bytes are added to each packet), 1/6 data field interleaving and 2/3 rate trellis coding. The randomization and FEC processes are not applied to the sync byte of the transport packet, which is represented in transmission by a Data Segment Sync signal as described below. Following randomization and forward error correction processing, the data packets are formatted into Data Frames for transmission and Data Segment Sync and Data Field Sync are added.

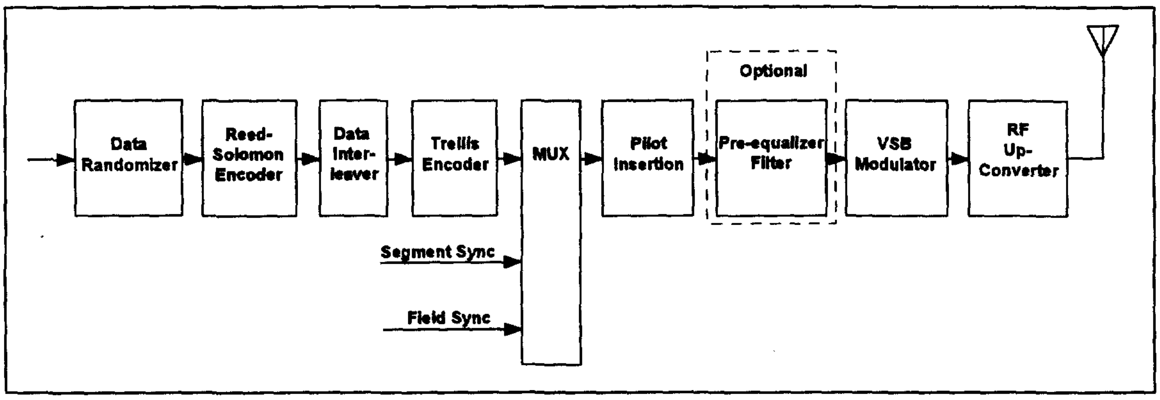

Figure 1. VSB transmitter.

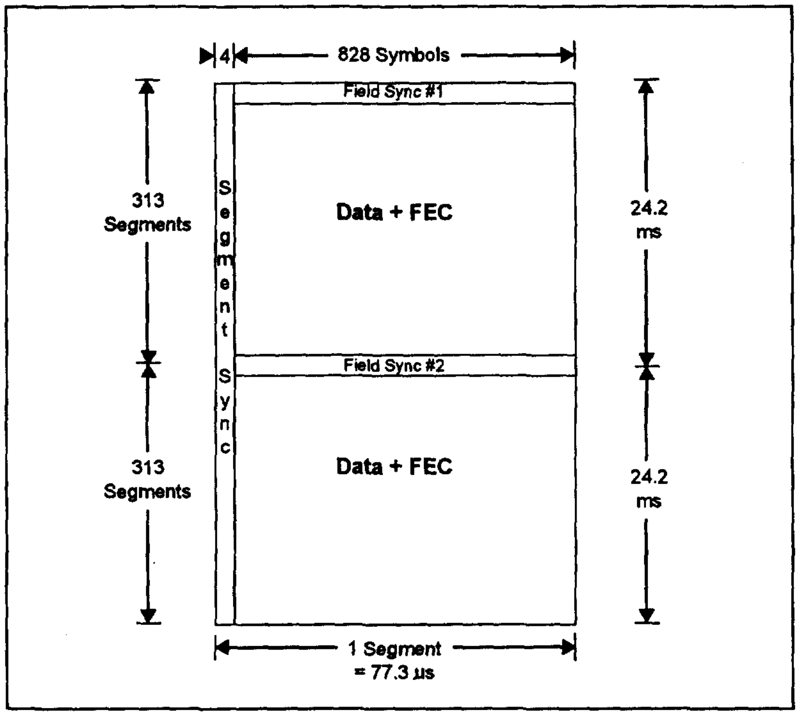

Figure 2. VSB data frame.

Figure 2 shows how the data are organized for transmission. Each Data Frame consists of two Data Fields, each containing 313 Data Segments. The first Data Segment of each Data Field is a unique synchronizing signal (Data Field Sync) and includes the training sequence used by the equalizer in the receiver. The remaining 312 Data Segments each carry the equivalent of the data from one 188-byte transport packet plus its associated FEC overhead. The actual data in each Data Segment comes from several transport packets because of data interleaving. Each Data Segment consists of 832 symbols. The first 4 symbols are transmitted in binary form and provide segment synchronization. This Data Segment Sync signal also represents the sync byte of the 188-byte MPEG-compatible transport packet. The remaining 828 symbols of each Data Segment carry data equivalent to the remaining 187 bytes of a transport packet and its associated FEC overhead. These 828 symbols are transmitted as 8-level signals and therefore carry three bits per symbol. Thus, 828 x 3 = 2484 bits of data are carried in each Data Segment, which exactly matches the requirement to send a protected transport packet:

187 data bytes + 20 RS parity bytes = 207 bytes
207 bytes x 8 bits/byte = 1656 bits
2/3 rate trellis coding requires 3/2 x 1656 bits = 2484 bits.

The exact symbol rate is given by equation 1 below:

(1) S_r (MHz) = 4.5/286 x 684 = 10.76... MHz

The frequency of a Data Segment is given in equation 2 below:

(2) $f_{seg} = S_r / 832 = 12.94... \times 10^3$ Data Segments/s.

The Data Frame rate is given by equation (3) below:

(3) $f_{frame} = f_{seg}/626 = 20.66$ ... frames/s.

The symbol rate S_r and the transport rate T_r (see Section 7.2 of Annex C) shall be locked to each other in frequency.

The 8-level symbols combined with the binary Data Segment Sync and Data Field Sync signals shall be used to suppressed-carrier modulate a single carrier. Before transmission, however, most of the lower sideband shall be removed. The resulting spectrum is flat, except for the band edges where a nominal square root raised cosine response results in 620 kHz transition regions. The nominal VSB transmission spectrum is shown in Figure 3.

At the suppressed-carrier frequency, 310 kHz from the lower band edge, a small pilot shall be added to the signal.

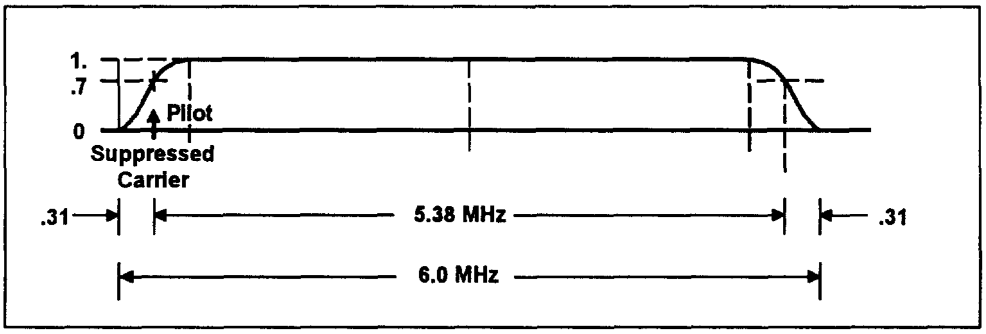

Figure 3. VSB channel occupancy (nominal).

4.2 Channel error protection and synchronization

4.2.1 Prioritization

All payload data shall be carried with the same priority.

4.2.2 Data randomizer

A data randomizer shall be used on all input data to randomize the data payload (not including Data Field Sync or Data Segment Sync, or RS parity bytes). The data randomizer XORs all the incoming data bytes with a 16-bit maximum length pseudo random binary sequence (PRBS) which is initialized at the beginning of the Data Field. The PRBS is generated in a 16-bit shift register that has 9 feedback taps. Eight of the shift register outputs are selected as the fixed randomizing byte, where each bit from this byte is used to individually XOR the corresponding input data bit. The data bits are XORed MSB to MSB ... LSB to LSB.

The randomizer generator polynomial is as follows:

$$G_{(16)} = X^{16} + X^{13} + X^{12} + X^{11} + X^7 + X^6 + X^3 + X + 1$$

The initialization (pre-load) to F180 hex (load to 1) occurs during the Data Segment Sync interval prior to the first Data Segment.

The randomizer generator polynomial and initialization is shown in Figure 4.

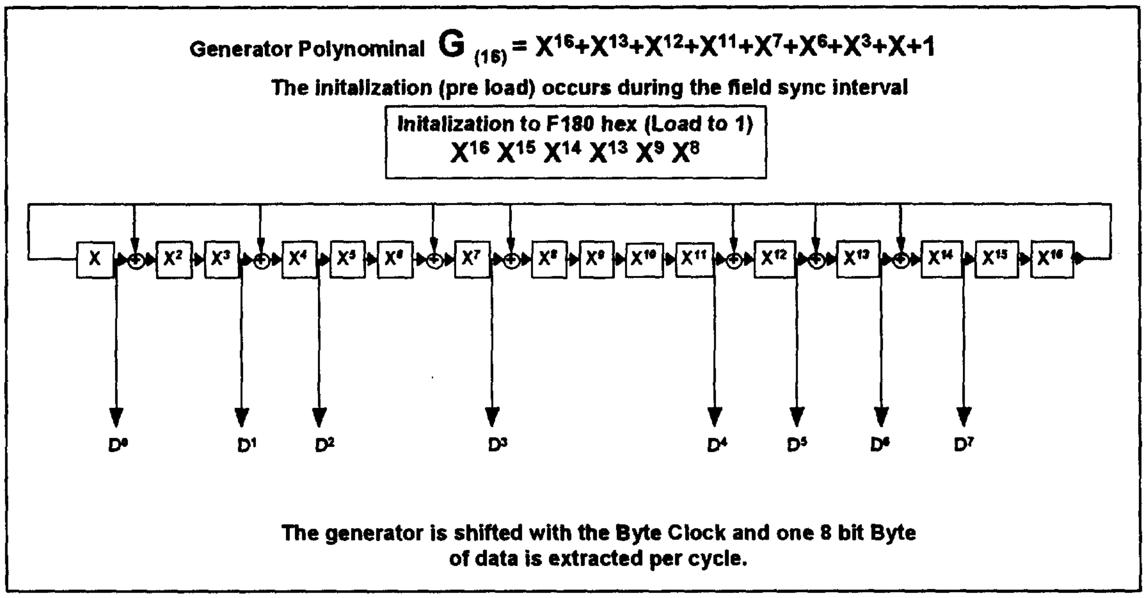

Figure 4. Randomizer polynomial.

4.2.3 Reed-Solomon encoder

The RS code used in the VSB transmission subsystem shall be a t = 10 (207,187) code. The RS data block size is 187 bytes, with 20 RS parity bytes added for error correction. A total RS block size of 207 bytes is transmitted per Data Segment.

In creating bytes from the serial bit stream, the MSB shall be the first serial bit. The 20 RS parity bytes shall be sent at the end of the Data Segment. The parity generator polynomial and the primitive field generator polynomial are shown in Figure 5.

4.2.4 Interleaving

The interleaver employed in the VSB transmission system shall be a 52 data segment (intersegment) convolutional byte interleaver. Interleaving is provided to a depth of about 1/6 of a data field (4 ms deep). Only data bytes shall be interleaved. The interleaver shall be synchronized to the first data byte of the data field. Intrasegment interleaving is also performed for the benefit of the trellis coding process.

The convolutional interleaver is shown in Figure 6.

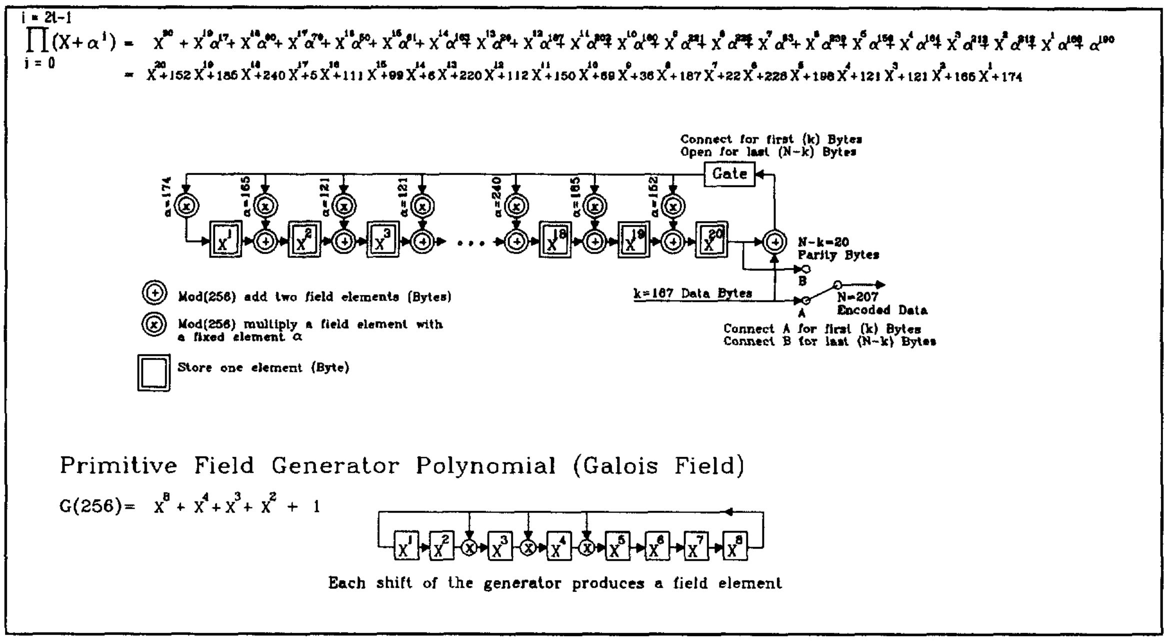

Figure 5. Reed-Solomon (207,187) t=10 parity generator polynomial.

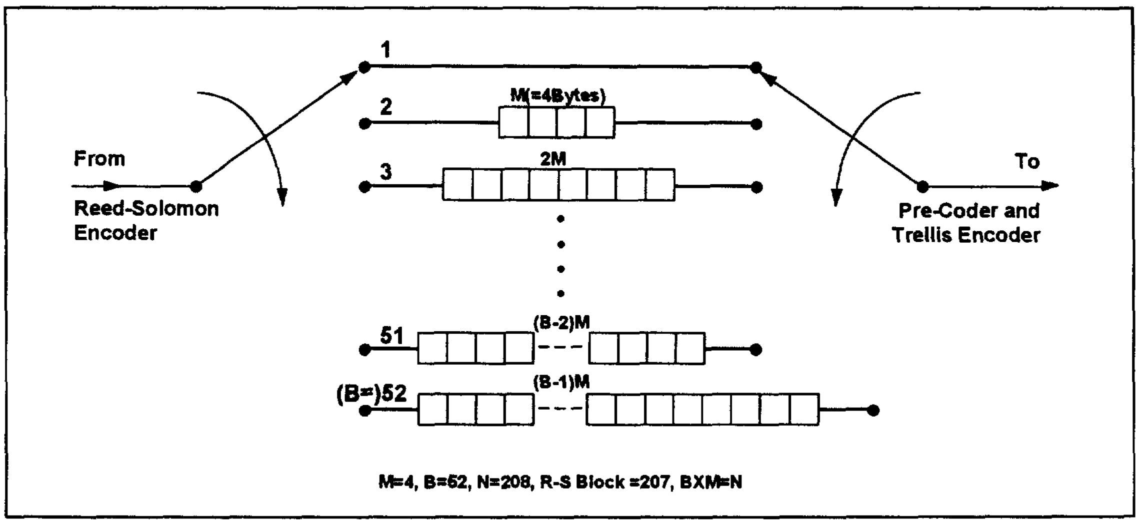

Figure 6. Convolutional interleaver (byte shift register illustration).

4.2.5 Trellis coding

The 8 VSB transmission sub-system shall employ a 2/3 rate (R=2/3) trellis code (with one unencoded bit which is precoded). That is, one input bit is encoded into two output bits using a 1/2 rate convolutional code while the other input bit is precoded. The signaling waveform used with the trellis code is an 8-level (3 bit) one-dimensional constellation. The transmitted signal is referred to as 8 VSB. A 4-state trellis encoder shall be used.

Trellis code intrasegment interleaving shall be used. This uses twelve identical trellis encoders and precoders operating on interleaved data symbols. The code interleaving is accomplished by encoding symbols (0, 12, 24, 36 ...) as one group, symbols (1, 13, 25, 37, ...) as a second group, symbols (2, 14, 26, 38, ...) as a third group, and so on for a total of 12 groups.

In creating serial bits from parallel bytes, the MSB shall be sent out first: (7, 6, 5, 4, 3, 2, 1, 0). The MSB is precoded (7, 5, 3, 1) and the LSB is feedback convolutional encoded (6, 4, 2, 0). Standard 4-state optimal Ungerboeck codes shall be used for the encoding. The trellis code utilizes the 4-state feedback encoder shown in Figure 7. Also shown is the precoder and the symbol mapper. The trellis code and precoder intrasegment interleaver is shown in Figure 8 which feeds the mapper shown in Figure 7. Referring to Figure 8, data bytes are fed from the byte interleaver to the trellis coder and precoder, and they are processed as whole bytes by each of the twelve encoders. Each byte produces four symbols from a single encoder.

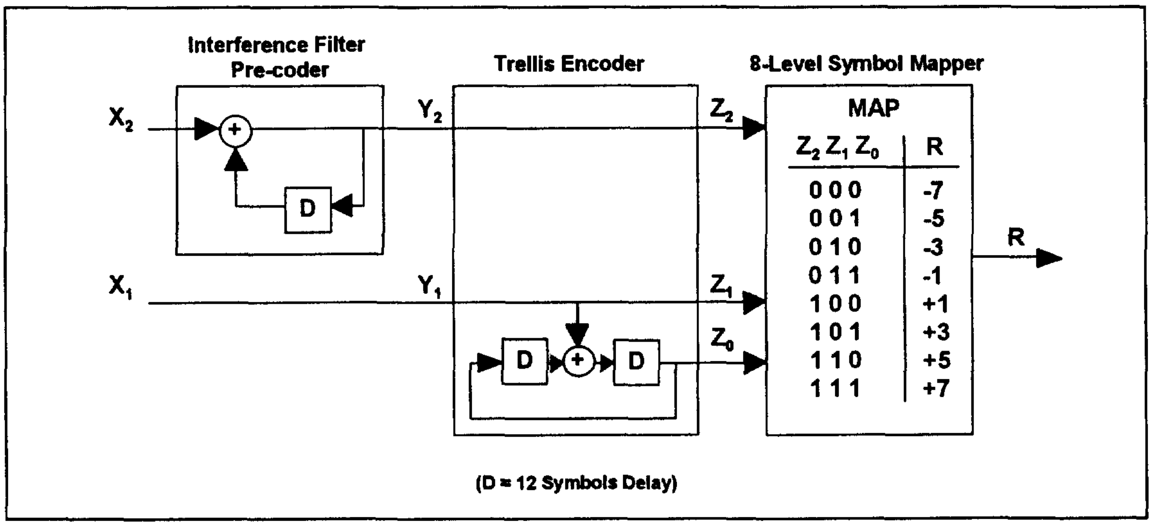

Figure 7. 8 VSB trellis encoder, precoder, and symbol mapper.

The output multiplexer shown in Figure 8 shall advance by four symbols on each segment boundary. However, the state of the trellis encoder shall not be advanced. The data coming out of the multiplexer shall follow normal ordering from encoder 1 through 12 for the first segment of the frame, but on the second segment the order changes and symbols are read from encoders 5 through 12, and then 1 through 4. The third segment reads from encoder 9 through 12 and then 1 through 8. This three-segment pattern shall repeat through the 312 Data

Segments of the frame. Table 1 shows the interleaving sequence for the first three Data Segments of the frame.

After the Data Segment Sync is inserted, the ordering of the data symbols is such that symbols from each encoder occur at a spacing of twelve symbols.

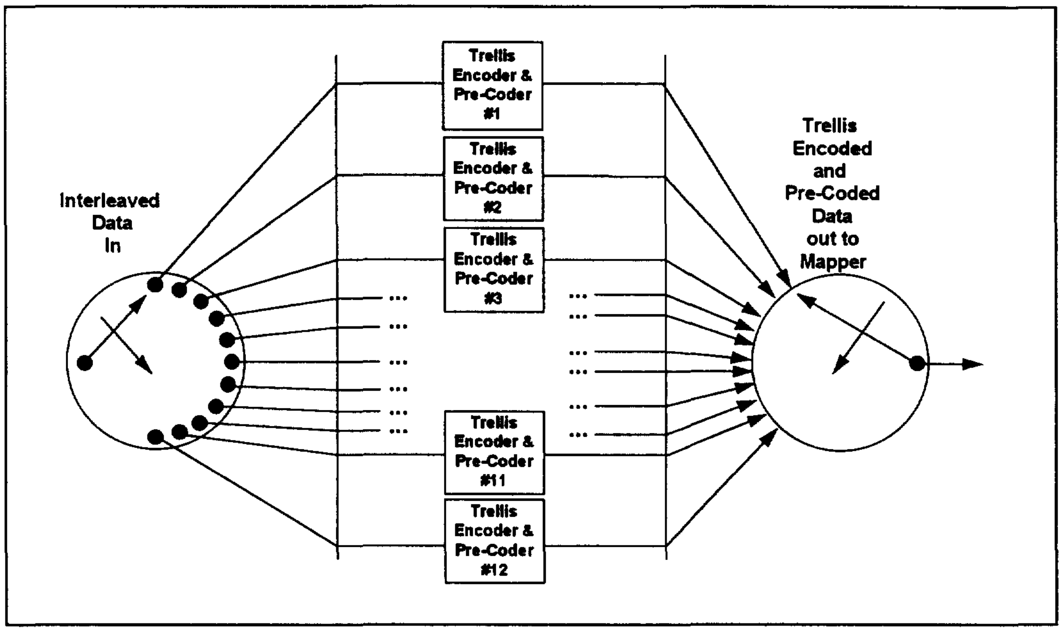

Figure 8. Trellis code interleaver.

Table 1 Interleaving Sequence

Segment	Block 1	Block 2	...	Block 69
1	D1 D2 D3 ... D12	D1 D2 D3 ... D12	...	D1 D2 D3 ... D12
2	D5 D6 D7 ... D4	D5 D6 D7 ... D4	...	D5 D6 D7 ... D4
3	D9 D10 D11 ... D8	D9 D10 D11 ... D8	...	D9 D10 D11 ... D8

4.2.6 Data Segment Sync

The encoded trellis data shall be passed through a multiplexer that inserts the various synchronization signals (Data Segment Sync and Data Field Sync).

A two-level (binary) 4-symbol Data Segment Sync shall be inserted into the 8-level digital data stream at the beginning of each Data Segment. (The MPEG sync byte shall be replaced by Data Segment Sync.) The Data Segment Sync embedded in random data is illustrated in Figure 9.

A complete segment shall consist of 832 symbols: 4 symbols for Data Segment Sync, and 828 data plus parity symbols. The Data Segment Sync is binary (2-level). The same sync pattern occurs regularly at 77.3 µs intervals, and is the only signal repeating at this rate. Unlike the data, the four symbols for Data Segment Sync are not Reed-Solomon or trellis encoded, nor are they interleaved. The Data Segment Sync pattern shall be a 1001 pattern, as shown in Figure 9.

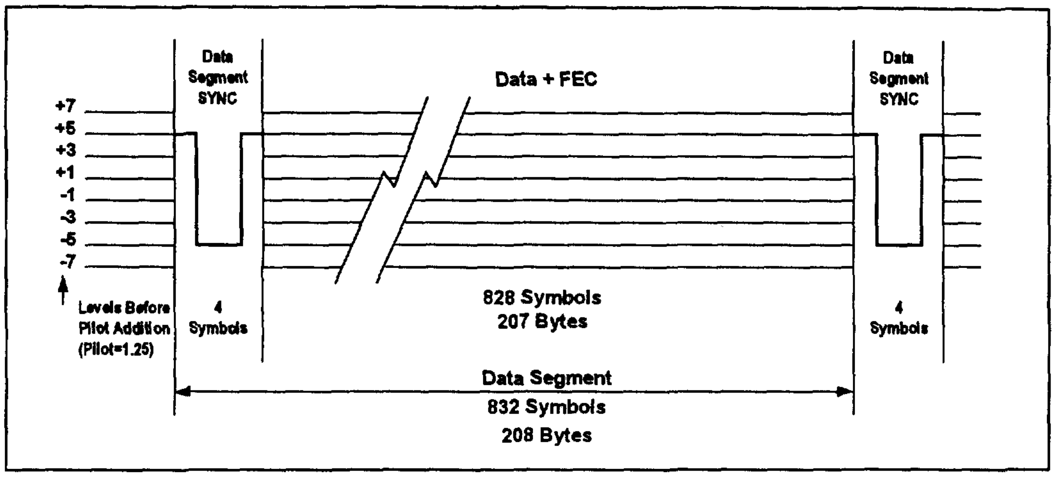

Figure 9. VSB data segment (terrestrial).

4.2.7 Data Field Sync

The data are not only divided into Data Segments, but also into Data Fields, each consisting of 313 segments. Each Data Field (24.2 ms) shall start with one complete Data Segment of Data Field Sync, as shown in Figure 10. Each symbol represents one bit of data (2-level). The 832 symbols in this segment are defined below. Refer to Figure 10.

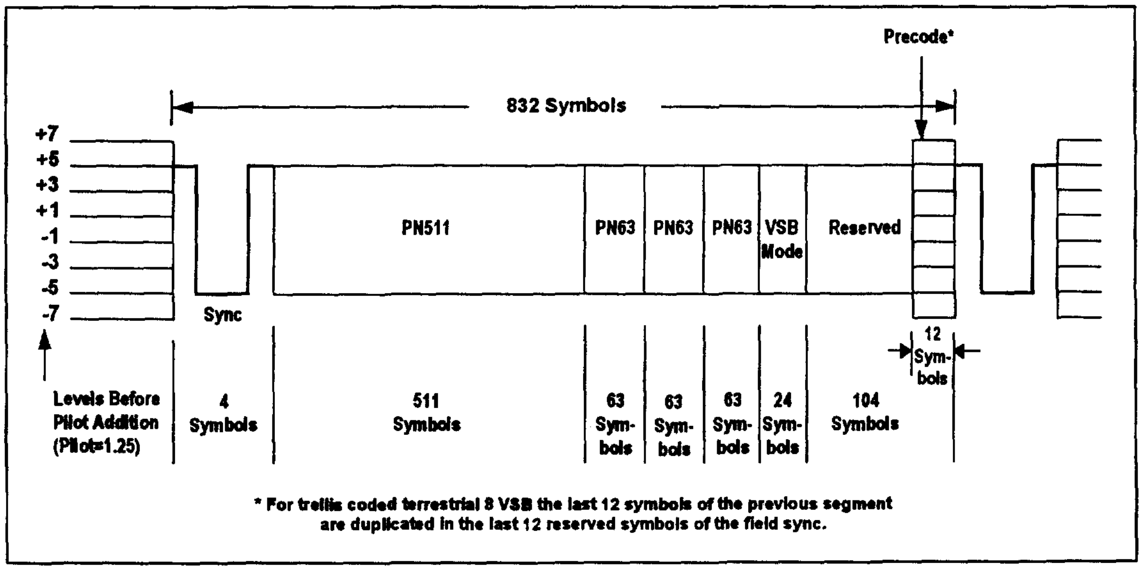

Figure 10. VSB Data Field Sync.

4.2.7.1 Sync

This corresponds to Data Segment Sync and is defined as 1001.

4.2.7.2 PN511

This pseudo-random sequence is defined as $X^9 + X^7 + X^6 + X^4 + X^3 + X + 1$ with a pre-load value of 010000000. The sequence is:

0000 0001 0111 1111 1100 1010 1010 1110 0110 0110 1000 1000 1001 1110 0001 1101
0111 1101 0011 0101 0011 1011 0011 1010 0100 0101 1000 1111 0010 0001 0100 0111
1100 1111 0101 0001 0100 1100 0011 0001 0000 0100 0011 1111 0000 0101 0100 0000
1100 1111 1110 1110 1010 1001 0110 0110 0011 0111 0111 1011 0100 1010 0100 1110
0111 0001 0111 0100 0011 0100 1111 1011 0001 0101 1011 1100 1101 1010 1110 1101
1001 0110 1101 1100 1001 0010 1110 0011 1001 0111 1010 0011 0101 1000 0100 1101
1111 0001 0010 1011 1100 0110 0101 0000 1000 1100 0001 1110 1111 1101 0110 1010
1100 1001 1001 0001 1101 1100 0010 1101 0000 0110 1100 0000 1001 0000 0001 110

4.2.7.3 PN63

This pseudo-random sequence is repeated three times. It is defined as $X^6 + X + 1$ with a pre-load value of 100111. The middle PN63 is inverted on every other Data Field Sync. The sequence is:

1110 0100 1011 0111 0110 0110 1010 1111 1100 0001 0000 1100 0101 0011 1101 000

The generators for the PN63 and PN511 sequences are shown in Figure 11.

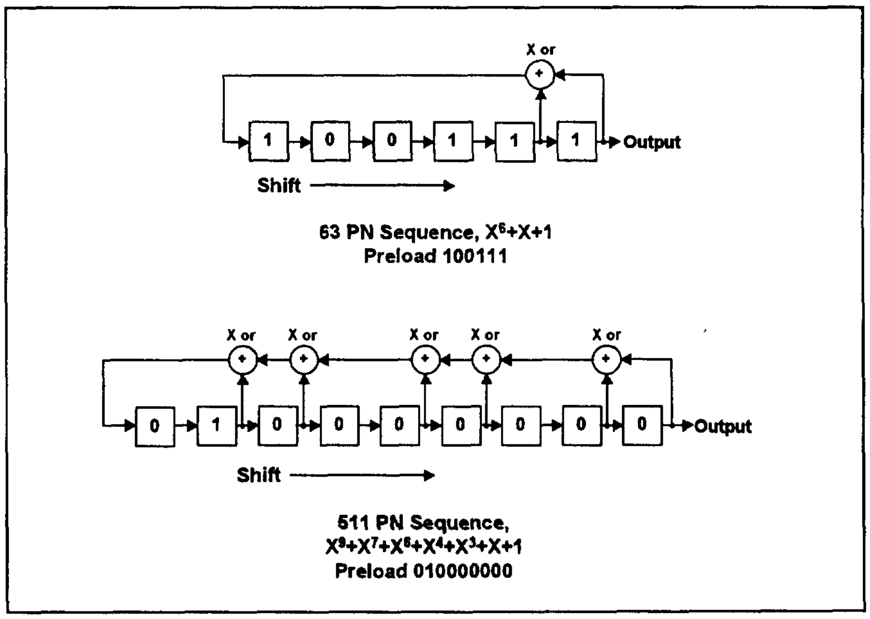

Figure 11. Field sync PN sequence generators.

4.2.7.4 VSB Mode

These 24 bits determine the VSB mode for the data in the frame. The first two bytes are reserved. The suggested fill pattern is 0000111100001111. The next byte is defined as:

P A B C $\overline{\text{P A B C}}$

where P is the even parity bit, the MSB of the byte, and A,B, C are the actual mode bits.

P A B C	
0 0 0 0	Reserved
1 0 0 1	Reserved
1 0 1 0	Reserved
0 0 1 1	Reserved
1 1 0 0	16 VSB Cable
0 1 0 1	8 VSB Terrestrial*
0 1 1 0	Reserved
1 1 1 1	Reserved

* In the 8 VSB terrestrial mode, the preceding bits are defined as :

0 0 0 0 $\overline{\text{P A B C}}$ P A B C 1 1 1 1

4.2.7.5 Reserved

The last 104 bits shall be reserved space. It is suggested that this be filled with a continuation of the PN63 sequence. In the 8 VSB mode, 92 bits are reserved followed by the 12 symbol definition below.

4.2.7.6 Precode

In the 8 VSB mode, the last 12 symbols of the segment shall correspond to the last 12 symbols of the previous segment.

All sequences are pre-loaded before the beginning of the Data Field Sync.

Like the Data Segment Sync, the Data Field Sync is not Reed-Solomon or trellis encoded, nor is it interleaved.

4.3 Modulation

4.3.1 Bit-to-symbol mapping

Figure 7 shows the mapping of the outputs of the trellis decoder to the nominal signal levels of (-7, -5, -3, -1, 1, 3, 5, 7). As shown in Figure 9, the nominal levels of Data Segment Sync and Data Field Sync are -5 and +5. The value of 1.25 is added to all these nominal levels after the bit-to-symbol mapping function for the purpose of creating a small pilot carrier.

4.3.2 Pilot addition

A small in-phase pilot shall be added to the data signal. The frequency of the pilot shall be the same as the suppressed-carrier frequency as shown in Figure 3. This may be generated in the following manner. A small (digital) DC level (1.25) shall be added to every symbol (data and sync) of the digital baseband data plus sync signal ($\pm$1, $\pm$3, $\pm$5,$\pm$7). The power of the pilot shall be 11.3 dB below the average data signal power.

4.3.3 8 VSB modulation method

The VSB modulator receives the 10.76 Msymbols/s, 8-level trellis encoded composite data signal (pilot and sync added). The ATV system performance is based on a linear phase raised cosine Nyquist filter response in the concatenated transmitter and receiver, as shown in Figure 12. The system filter response is essentially flat across the entire band, except for the transition regions at each end of the band. Nominally, the roll-off in the transmitter shall have the response of a linear phase root raised cosine filter.

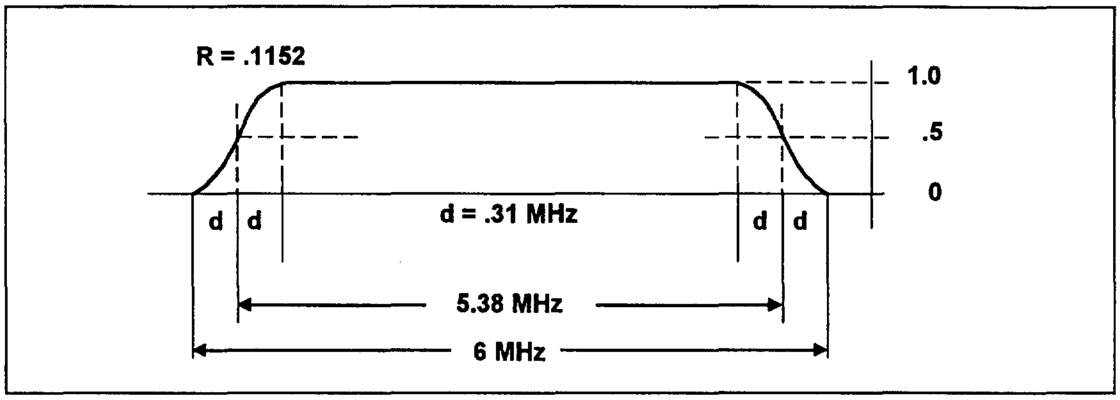

Figure 12. Nominal VSB system channel response (linear phase raised cosine Nyquist filter).

5. TRANSMISSION CHARACTERISTICS FOR HIGH DATA RATE CABLE MODE

5.1 Overview

The high data rate cable mode trades off transmission robustness (28.3 dB signal-to-noise threshold) for payload data rate (38.57 Mbps). Most parts of the cable mode VSB system are identical or similar to the terrestrial system. A pilot, Data Segment Sync, and Data Field Sync are all used to provide robust operation. The pilot in the cable mode also is 11.3 dB below the data signal power. The symbol, segment, and field signals and rates are all the same, allowing either receiver to lock up on the other's transmitted signal. Also, the data frame definitions are identical. The primary difference is the number of transmitted levels (8 versus 16) and the use of trellis coding and NTSC interference rejection filtering in the terrestrial system.

The RF spectrum of the cable modem transmitter looks identical to the terrestrial system, as illustrated in Figure 3. Figure 13 illustrates a typical data segment, where the number of data levels is seen to be 16 due to the doubled data rate. Each portion of 828 data symbols represents 187 data bytes and 20 Reed-Solomon bytes followed by a second group of 187 data bytes and 20 Reed-Solomon bytes (before convolutional interleaving).

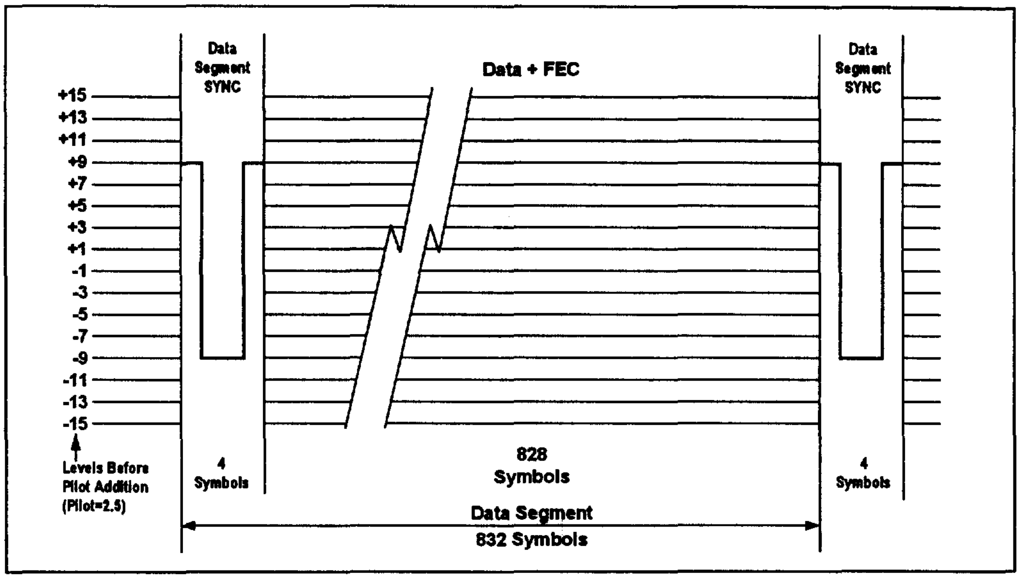

Figure 13. VSB data segment (cable).

Figure 14 shows the block diagram of the transmitter. It is identical to the terrestrial VSB system except the trellis coding shall be replaced with a mapper which converts data to multi-level symbols. See Figure 15.

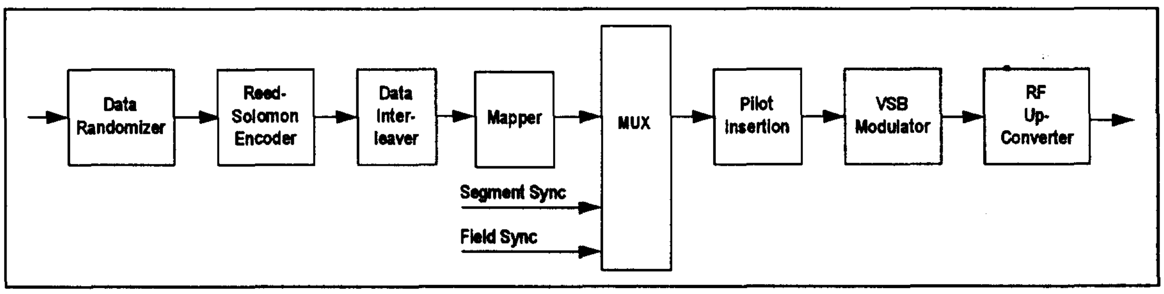

Figure 14. 16 VSB transmitter.

5.2 Channel error protection and synchronization

5.2.1 Prioritization

See Section 4.2.1.

5.2.2 Data randomizer

See Section 4.2.2.

5.2.3 Reed-Solomon encoder

See Section 4.2.3.

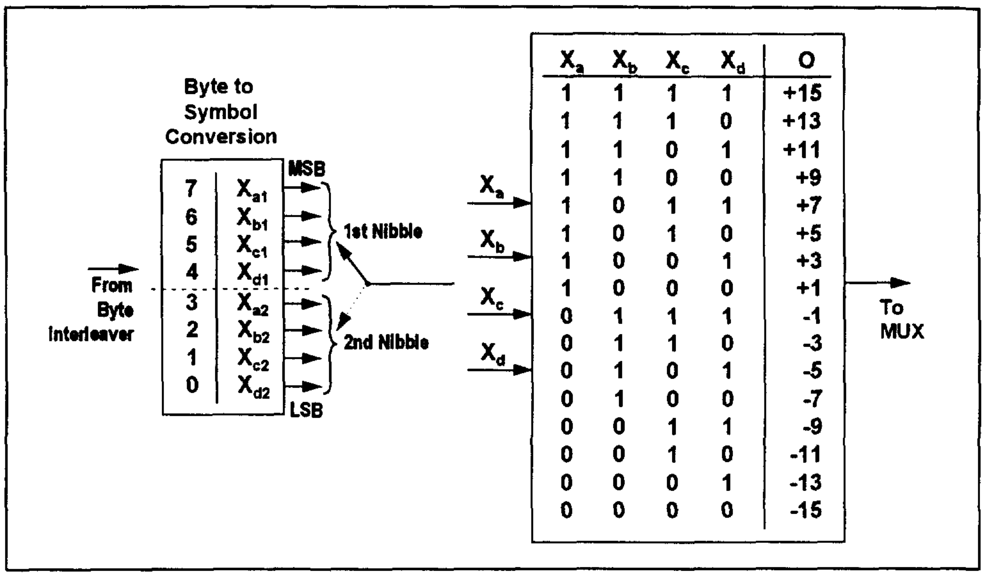

Figure 15. 16 VSB mapper.

5.2.4 Interleaving

The interleaver shall be a 26 data segment inter-segment convolutional byte interleaver. Interleaving is provided to a depth of about 1/12 of a data field (2 ms deep). Only data bytes shall be interleaved.

5.2.5 Data Segment Sync

See Section 4.2.6.

5.2.6 Data Field Sync

See Section 4.2.7.

5.3 Modulation

5.3.1 Bit-to-symbol mapping

Figure 15 shows the mapping of the outputs of the interleaver to the nominal signal levels (-15, -13, -11, ..., 11, 13, 15). As shown in Figure 13, the nominal levels of Data Segment Sync and Data Field Sync are -9 and +9. The value of 2.5 is added to all these nominal levels after the bit-to-symbol mapping for the purpose of creating a small pilot carrier.

5.3.2 Pilot addition

A small in-phase pilot shall be added to the data signal. The frequency of the pilot shall be the same as the suppressed-carrier frequency as shown in Figure 3. This may be generated in the following manner. A small (digital) DC level (2.5) shall be added to every symbol (data and sync) of the digital baseband data plus sync signal (±1, ±3, ±5, ±7, ±9, ±11, ±13, ±15). The power of the pilot shall be 11.3 dB below the average data signal power.

5.3.3 16 VSB modulation method

The modulation method shall be identical to that in Section 4, except the number of transmitted levels shall be 16 instead of 8.

ANNEX E

(Informative)

RECEIVER CHARACTERISTICS

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